

**A US COORDINATION FACILITY FOR THE SPECTRUM-X-GAMMA
OBSERVATORY**

NASA Grant NAG5-8358

Annual Report

For period from 1 February 1999 through 30 July 1999

Principal Investigator
Dr. W. Forman

August 1999

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The U.S. Spectrum-X Gamma Coordination Facility

August 16, 1999

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1 Introduction

Spectrum-X Gamma (SXG) is a world-class, orbiting astronomical observatory, with capabilities for all-sky monitoring, polarimetry, and high resolution spectroscopy, and wavelength coverage extending from the ultraviolet (TAUVEX and FUVITA), through the x-ray (SODART and JET-X), to the hard x-ray (MART), and gamma-ray (SPIN) regimes. SXG is a multi-national mission developed under the sponsorship of the Russian Academy of Sciences, with participation from several European countries and the U.S. The U.S. involvement in SXG includes both instrumentation and data rights. The U.S. Spectrum-X Gamma Coordination Facility (SXGCF) supports U.S. observers in proposing for SXG SODART observations, analyzing SXG data, and conducting archival research. The SXGCF also has the responsibility for organizing the U.S. archive of SXG data, which will eventually include approximately half of the data from most SXG instruments. This report summarizes the activities of the SXGCF scientific and technical staff during the period from Feb. 1 through July 31, 1999.

2 Overall Mission Support

The SXGCF has a responsibility to act as an advocate for SXG, both to the U.S. astronomical community at large and also to groups which influence national space science policy. This activity is particularly important now, since repeated launch delays have placed SXG in direct competition for community interest and resources with other major x-ray astronomy missions such as Chandra (already in operation), or XMM and Astro-E (both to be launched before SXG). We prepared a detailed report comparing SXG's capabilities to those of Chandra, XMM, and Astro-E, emphasizing the unique scientific opportunities offered by SXG. We presented our results during the June 16-18 meeting of the "Structures and Evolution of the Universe" Subcommittee (SEUS) of NASA's Space Sciences Advisory Committee. Sample figures from the report are shown in Figures 1 - 3.

During the time interval covered by this report, we also conducted a review of our web site www-hea.harvard.edu/SXG/sxg.shtml, to remove out-of-date references to other web sites and to update information on SXG instruments and participating institutions. An on-line version of the SXG SODART Observer's Guide is ready for inclusion in our web site in August.

Finally, we prepared a final report for the project.

3 Software Research

Although software development is not a primary function of the SXGCF, we continue to investigate astronomical software, developed elsewhere, which may be useful in analyzing SXG data. During the time period covered by this report, we initiated discussions with colleagues at the Danish Space Research Institute (DSRI) and the Astrophysical Institute of Potsdam (AIP) to learn the status of their software to simulate and analyze OXS observations and to determine whether we can assist in their efforts. The OXS is perhaps the most

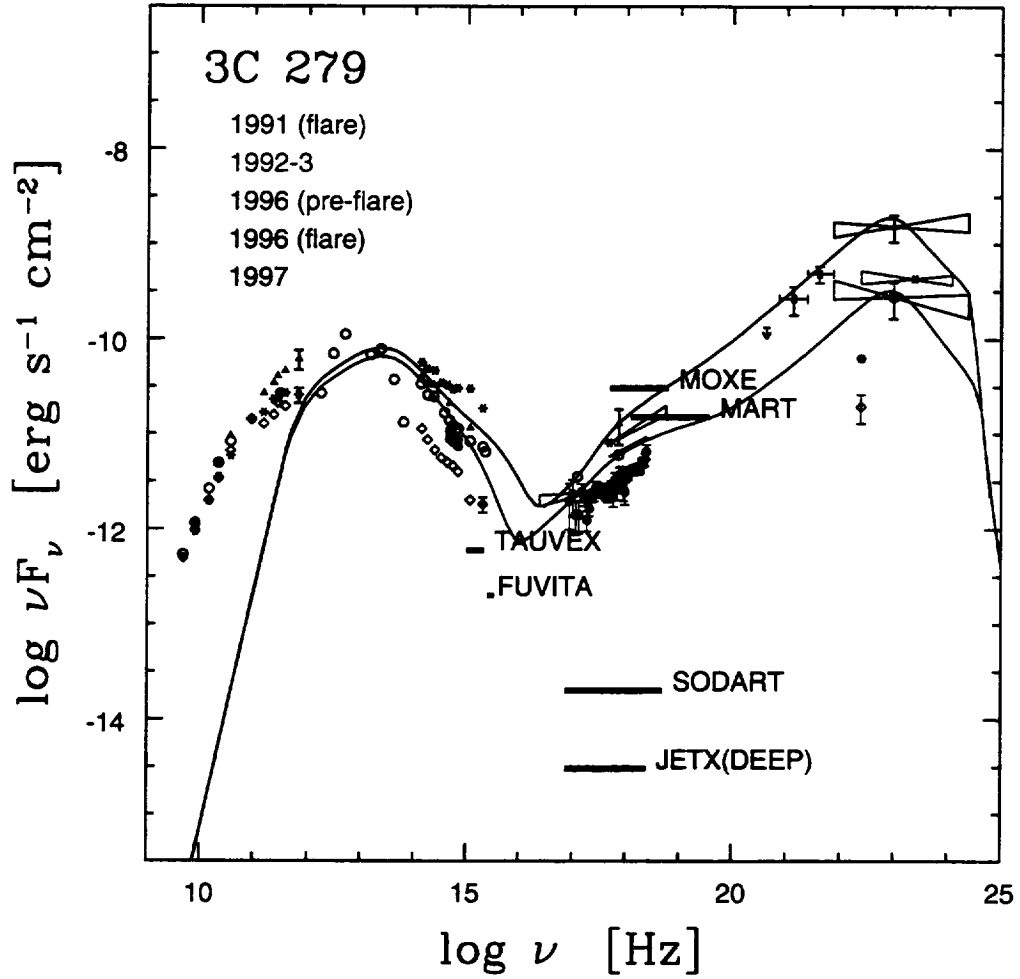


Figure 1: SXG provides simultaneous, broad-band coverage at energies from the far UV through hard x-ray. SXG instrument sensitivities for typical observation times (≤ 1 day) will easily allow simultaneous, multi-wavelength monitoring campaigns for objects fainter than the QSO 3C 279.

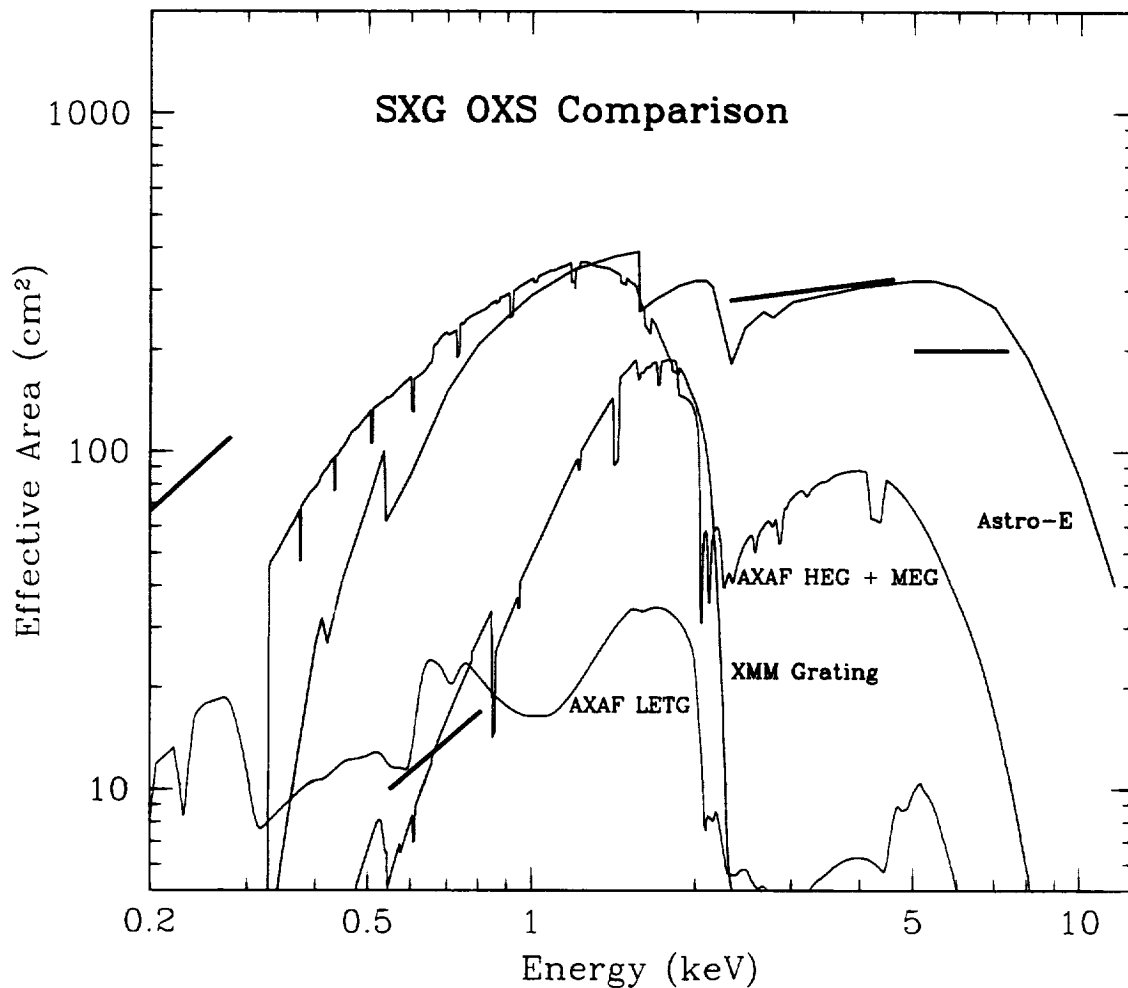


Figure 2: SXG's Objective Crystal Spectrometer (OXS) provides high resolution spectroscopy with sensitivities comparable to Chandra, XMM, and Astro-E above .5 keV, and is unchallenged at the lowest energies. In addition, SXG's large $\sim 1^\circ$ field-of-view allows high resolution spectroscopic observations of entire clusters, impossible with other instruments.

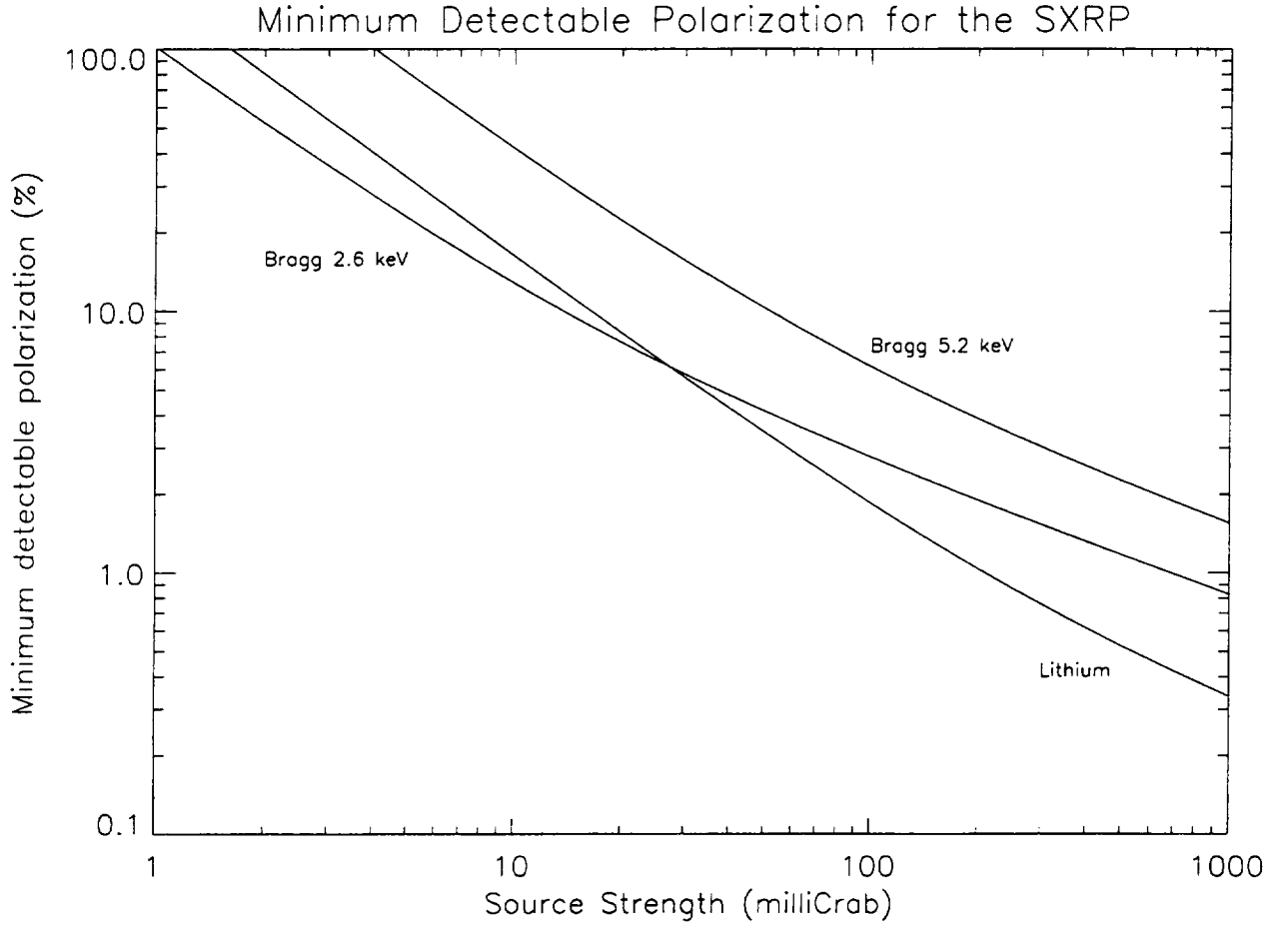


Figure 3: Sensitivity for SXP for the two Bragg energy bands and for the Lithium crystal (> 5 keV) for a 100ksec observation. SXP allows polarization measurements of galactic sources (at the 1% level in 100ksec). In 100ksec, 10% polarization can be detected for the brighter extra-galactic sources. For bright, compact, galactic X-ray sources, polarizations can be measured as a function of pulse and binary orbital phases.

attractive SXG instrument in the Chandra-XMM-Astro-E era, and we anticipate a high degree of interest from U.S. observers in such software.

We also researched ZHTOOLS, an analysis toolkit developed by A. Vikhlinin for JET-X data analysis. ZHTOOLS include a number of generally applicable x-ray spatial and spectral analysis tools. We previously developed an SAOtng interface to some of them, and plan to make the full suite available to U.S. SXG observers.

We participated in beta tests of DS9, the successor to SAOtng, developed by the SAO HEAD Research and Development Group. An example of a DS9 image display of a simulated SXG SODART HEPC x-ray event list is shown in Figure 4. Since SAOtng figures prominently in the set of analysis tools we plan to support for SXG, it is important that we verify that new versions of it can still meet our needs. Our tests of DS9 did verify that it can display SXG-formatted data, but also indicated an X server bug, which is currently being pursued by the R&D group.

In order to keep abreast of software development efforts for other x-ray missions, we have also participated in testing Chandra data analysis software, including Data Model tools and routines for modeling background in x-ray images. These latter tools, shown in Figure 5, should be directly applicable to SXG image analysis. Finally, we investigated SExtractor, an optical photometry program developed by Bertin and Arnouts (1996, *A&AS*, 117, 393). This code may be quite valuable in modeling background in x-ray images.

4 Scientific Activities

In order to appreciate the scientific needs of U.S. SXG observers, the scientific staff of the SXGCF are expected to conduct vigorous programs in x-ray astronomy themselves. The research activities of SXGCF scientists during the time period covered by this report are summarized below.

4.1 Research Activities of W. Forman

With Nevalainen and Marklevitch, cluster mass distributions were studied. The goal of this study is to derive the cluster mass distributions to large radii. These masses will then be compared to masses of cooler systems to derive a mass-temperature relation to understand the correspondence between temperature and total mass and to investigate processes which alter the theoretically predicted relation. We used ASCA and ROSAT data to derive the mass distribution in A401, a dynamically relaxed cluster. A paper, The Baryonic and Dark Matter Distributions in Abell 401, was prepared and has been accepted for publication (for a preprint see astro-ph/9906286). A second paper, on A3571, another massive (hot) relaxed cluster was prepared and submitted. The final paper in the series, The cluster M-T relation from temperature profiles observed with ASCA and ROSAT, was completed and submitted. It combines the masses of the two hot clusters, A401 and A3571 with published data for A2256 and A2029 as the hottest cluster sample, with masses for two intermediate temperature clusters, A496 and A2199, and three cool groups, NGC5044, HCG62, and NGC507. The paper shows that the mass-temperature relation is slightly, but significantly steeper than the predicted relation. This result is consistent with the break-down of self-similar scaling at

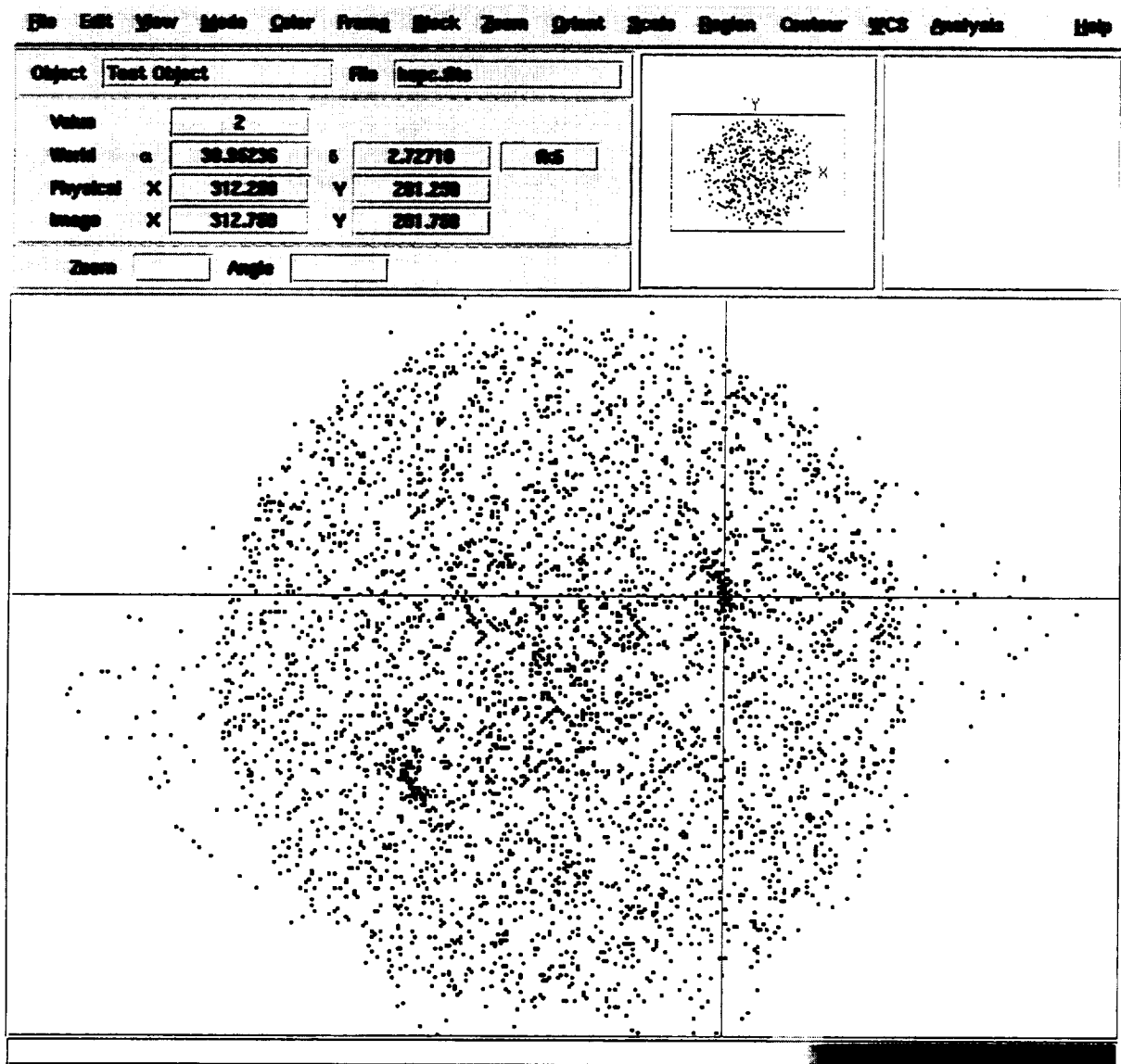


Figure 4: A simulated SXG HEPC image, displayed by DS9, the successor to SAOtnng.

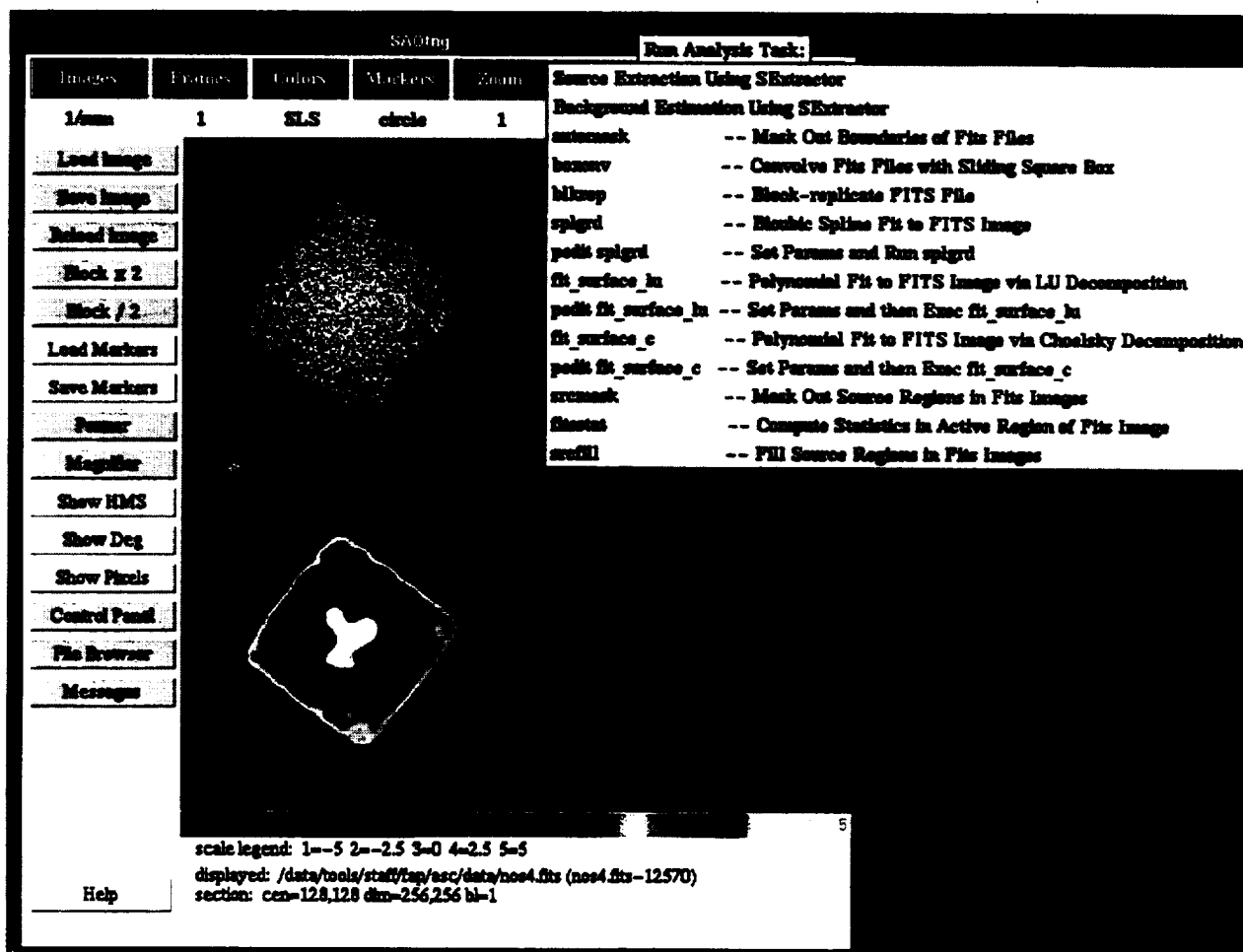


Figure 5: An SAOtnng interface to tools useful for background estimation in x-ray images. The tools include the optical source extraction code SExtractor (Bertin & Arnouts 1996, A&AS, 117, 393), as well as a number of tools developed for the CSC, all of which can be executed by SAOtnng. The upper panel displays a simulated Chandra HRC image. The lower left displays the fitted background, using the `fit_surface_lu` task, and the lower right panel displays the residuals. All three panels have the same scale and colormap.

low temperatures where energy injection by supernova driven galactic winds can significantly effect the overall energy balance of the intra-cluster medium.

Ongoing cluster studies include an investigation of ASCA derived temperatures of clusters of galaxies using the algorithm described in Churazov et al. (1996, ApJ, 471, 673). In particular, we are studying the temperature maps of merging clusters and comparing these to numerical simulations to study the shocked regions between the merging components. We are completing a detailed investigation of the complex morphology of the core of the Perseus cluster, surrounding NGC1275. The X-ray and radio morphologies of this cooling flow cluster suggest a variety of possible origins. A paper discussing these has been prepared and submitted.

Finally, we are completing the study of A1689 which shows that the discrepant masses derived by X-ray and gravitational lensing techniques can be reconciled by the optical data. The optical data show that A1689 is actually a projection along the line of sight of three mass components. This suggests that we are looking along a large scale filament and that, since lensing measures the surface mass density projected along the line of sight, it is naturally larger than that measured in the X-rays which is sensitive only to that mass which has collapsed into the main cluster and, therefore, is measured over a much smaller volume.

4.1.1 Papers Published since February 1999:

A ROSAT PSPC Observation of the Lensing Cluster A1689 (with S.Daines and C. Jones), Ap.J. accepted.

A Hot Spot in Coma (with H. Donnelly, C. Jones, M. Markevitch, E. Churazov, and M. Gilfanov) 1999ApJ, 513, 690

Stellar Metallicities and Type IA Supernova Rates in the Early-Type Galaxy NGC 5846 from ROSAT and ASCA Observations (with FINOGUENOV, A.; JONES, C, FORMAN, W.; DAVID, ApJ, 514, 844

Constraining q_0 with Cluster Gas Mass Fractions: A Feasibility Study (with K. Rines, C. Jones, U. Pen, and R. Burg) ApJ, 517, 70

ROSAT PSPC Observations of the Richest ($R \geq 2$) ACO Clusters (with L. David and C. Jones) ApJ, 519, 533

X-ray Over-Luminous Elliptical Galaxies: A New Class of Mass Concentrations in the Universe? (with A. Vikhlinin, B.R. McNamara, A. Hornstrup, H. Quintana, C. Jones, M. Way) ApJ, 520L, 1

Evidence for Merging in the Centaurus Cluster (with E. Churazov, M. Gilfanov, C.Jones) ApJ, 520, 105

4.1.2 Proposals Submitted:

As the PI, W. Forman submitted an XMM proposal to investigate the detailed structure and temperature distribution of A1367. He also joined as co-I to study the distant, lensing clusters CL0024+16 and CL2244-02 as well as the nearby Perseus cluster to investigate its detailed structure and the interaction between the radio plasma and the cooling gas in the cluster core.

4.2 Research Activities of C. Jones

Dr. Jones collaborated with Dr. Forman on a number of the research activities described in section 4.1. In addition, With summer intern Vit Hradecky, Dr. Jones determined the X-ray mass profiles and cluster galaxy masses for a sample of 7 clusters and one group, and measured mass-to-light ratios of about 100 (in solar units) within a 1 Mpc radius. These mass-to-light ratios imply a low density Universe, with a value of about 0.2 for Omega.

Dr. Jones' Education and Public Outreach activities included preparing materials to be used to conduct a teacher workshop on Life in the Universe, to be held in the early fall; in collaboration with the CfA Science Media Group, she is also writing and producing a series of video workshops on light.

4.2.1 Papers Published:

In addition to the papers cited in section 4.1.1, Dr. Jones delivered an invited paper on Chandra Images of X-ray Lenses at the conference on Gravitational Lensing held in July at Boston University. The paper was published in the conference proceedings:

"Chandra Images of X-ray Clusters" C. Jones, Conference on Gravitation Lensing, Boston University, July 1999.

4.2.2 Proposals Submitted:

Several XMM proposals to observe clusters were submitted.

4.3 Research Activities of H. Schnopper

The development of thin plastic foil optics was continued. Several new point to point focusing optics were constructed. Among them were the first that were built up from individual, full shells of revolution. One was 2 inch diameter and was made with, 19 gold coated plastic shells that are 2 inches long. Another, 8 inches in diameter was made with 4 gold coated shells that are 4 inches long. These optics were tested in a long pipe facility located at the Palermo Observatory. The test results are extremely promising. Additional testing of x-ray optics will take place in facilities at SUNY, Albany.

Laboratory work continued on the thin foil project with new plastic foils being sought for evaluation.

Development of a test facility for the PLEXUS project polarimeter studies resulted in a design for a rotate-able, 100 percent polarized X-ray source that will be used to evaluate the multi-layer polarimeter. The polarimeter is now under construction and will be inserted in multipurpose beam pipe that is also under construction.

4.3.1 Papers Published:

"X-ray Optics Made from Thin Plastic Foils" Schnopper et al, presented at the 1999 SPIE meeting in Denver on 19 July.

"XRASE: the X-ray Spectroscopic Explorer", E. Silver and H. Schnopper, was presented at the January AAS meeting in Austin.

“XRASE: the X-ray Spectroscopic Explorer”, was presented as an invited paper at the MINISAT 01 meeting in April. It will be published in *Astrophysics and Space Science*.

4.4 Research Activities of F. Primini

F. Primini continued to work on the ROSAT HRI survey of the disk of M31, in collaboration with E. Magnier of U. Washington. He developed a software fix for incorrectly interpolated aspect solutions, present in most HRI observations. This work was necessary to improve the spatial resolution of the HRI images in the vicinity of the nucleus. This is important both for more accurate astrometry and also for increased sensitivity to faint x-ray sources near the nucleus. He also debugged RSDC software for generating HRI exposure maps, and generated correct exposure maps for all observations in the survey, as well as an exposure-corrected intensity map of all data in the survey. He also extracted interesting objects from a number of astronomical catalogs of cross-referencing with survey x-ray sources.

He collaborated with G. Trinchieri of Brera Astronomical Observatory on a paper reporting the results of BeppoSax observations of M31.

4.4.1 Papers Published:

Broad-Band X-ray Spectra of M31 Sources with BeppoSAX (G. Trinchieri, G. Israel, L. Chiappetti, T. Belloni, L. Stella, F. Primini, G. Fabbiano, & W. Pietsch), *A&A* accepted.

4.4.2 Proposals Submitted:

As PI, he submitted an XMM proposal to measure the spectrum of the nuclear x-ray source in the nearby galaxy NGC3115. He was also co-investigator on an LTSA proposal to search for white dwarfs in Chandra M31 observations and co-investigator on an NSF proposal to develop a knowledge data base of data analysis algorithms useful for x-ray astronomy applications.

